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Physiological Studies on the Eel.
III. Microscopical Observations of the Blood[1]

(Plate I.)

By

Nobuyuki KAWAMOTO

(Received December 5th, 1930.)

The microscopical observations of the blood of fishes have been made by Drzewina[2] ('10), Harris[3] ('03), Knoll[4] ('96), Lanine[5] ('12), Sabrazés and Muratet[6] ('08) Nakanoin[7] ('19), and many other investigators, but so far as I know no complete report has appeared on the morphology of the blood of the eel. I shall therefore write on the microscopical observations which I made during my study of the blood gases of the eel (*op. cit.*).

I must express my hearty thanks to Prof. Tadashi Higurashi and Prof. Dr. Arata Terao who have encouraged me throughout my study and to Prof. Etuzo Komiya, of the Kumamoto Medical College, and to Drs. Yosio Mikamo and Otohiko Kosyô who gave me valuable suggestions on this subject.

Material and Methods.

All the eels (*Anguilla japonica* T. et S.) which were used for the morphological observations of the blood were almost equal in size,

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 9. The first and second installments of the present work have appeared in Sci. Rep. Tôhoku Imp. Univ., Ser. IV, 4 (4), 1929.

2) Drzewina, A. '10. C. R. Mém. Soc. Biol., Paris, **68** : 112—113.

3) Harris, D. F. '03. Jour. Physiol. **30** : 319—321.

4) Knoll P. '96. Sitzber. Akad. Wiss. Wien, **105** (3) : 35—66.

5) Lanine, P. '12. Arch. Biol. Liège, **27** : 525—574.

6) Sabrazés et Muratet. '08. Act. Soc. Linn. Bordeaux **62** : 113—117.

7) Nakanoin, K. '19. Kyôto Igaku Zasshi (Kyôto Medical Journal), **18** (2—3).

weighing about 80 grams. But a number of much larger and smaller individuals were also used for counting the number of the blood corpuscles.

The blood was examined fresh soon after being taken directly from the heart of the eel by injecting an apparatus, and slides were also prepared by fixing the blood with methyl alcohol aud staining it with Giemsa, May-Giemsa, May-Grünwald, and other solutions. For the observations of the oxydase and peroxydase reactions Schultze's and Freisch's methods[1] were used respectively.

Observations.

In the fresh materials under the microscope I could distinguish only two types of corpuscles: red blood-corpuscle, i. e., erythrocyte, and colourless blood-corpuscle. The former is oval, 13—16μ × 6—8μ in diameter, 2—3μ in thickness, and yellowish green in colour (Pl. I, figs. 4, 5), with an oval nucleus projecting in the center of the cell (Pl. I, figs. 6, 7). On the other hand, colourless corpuscle has no fixed form. In this type of the corpuscle, I could distingiush lymphocyte, monocyte, neutrophil leucocyte and thrombocyte[2] by the already mentioned methods of fixing and staining. I shall explain my observations of the slides in the following paragraphs.

Erythrocyte (Pl. I, figs. 1—3). By May-Grünwald's and May-Giemsa's stainings, the protoplasm stained red and sometimes a few small round granules could be seen in it and the nucleus stained dark violet and the chromatin net-work could be clearly made out.

Lymphocyte: The form was irregular and lobed pseudopodia were seen (Pl. I, figs. 8–12, 24–31), the protoplasm was spongioplasm and stained a blue color as it was basic, the nucleus was red-violet with May-Grünwald, violet-red with May-Giemsa, the diameters were 5–6μ and divided into two types in their forms, some being smaller and some being larger. The smaller forms had comparatively large nuclei in spite of the cells being small and therefore are called "small lymphocytes" (Pl. 1, figs. 8, 9, 24, 25), on the other hand the larger ones had a large proportion of protoplasm containing sometimes a few Kurlow-like granules (Pl. I, figs. 11, 12, 27, 28, 29, 31) called "large lymphocytes",

1) Domarus, A. V. '21. Methodik der Blutuntersuchung. Berlin.

2) Kiyono, K. '20. Present Status of the Studies on the Vital Staining, with Special Reference to the Technique (in Japanese), Tokyo, pp. 375—377.

and the nuclei of these larger ones were almost kidney-shaped or lobed, probably in their developing stage.

These two varieties have been also seen in pike[1] and other fishes.

Monocyte: The cells were largest in the normal corpuscles (Pl. I, figs. 17–19, 36–41) 12–15μ in diameter in the smears, the form of the cells was almost round and the nuclei were oval, lobed or kidneyshaped. The cells much resemble the large lymphocytes, but are easily distinguished from the latter by the fine structure of their nuclei. Their protoplasm was basic and so stained deep blue, though occasionally I saw a part of it stain neutral. The color of the nucleus was the same as that of the lymphocyte.

Neutrophil leucocyte: The cells were round and their protoplasm stained light blue with May-Giemsa, and in the protoplasm could be seen many small stick-like granules which stained neutral color (Pl. I, figs. 32–35). However when May-Grünwald's dye was used, numerous small granules of light green color were observed in the protoplasm (Pl. I, figs. 13–16) The nuclei were round or sometimes kidney-shaped or lobed, according to the stage of development; and all were situated eccentrically. The diameters of these neutrophil leucocytes were 11–14μ in fixed material.

Thrombocyte: The shape of the cell was like a spindle, oval or elongated ellipsoidal, sometimes one end was round while the other end was pointed, long diameters were 10–13μ, short diameters were 3–5μ in fixed materials. The nuclei were oval or ellipsoidal, comparatively large and were situated in the obtuse end of the cell. In the protoplasm, could be observed many fine granules of light violet-red colour (Pl. I, figs. 20–23, 44–48).

In addition to the five different corpuscles above mentioned, the two cells, as presented in the Pl. I, figs. 42 and 43, were observed, the one seemed to be a monocyte or the developing stage of a neutrophil leucocyte, and the other resembled the lymphocyte but the granules could not be classified. Neither the eosinophil leucocyte, nor the mast-cell were found in my observations, although the existence of the eosinophil leucocyte in the blood of *Anago anago* (T. & S.) has been reported by Nakanoin (*op. cit.*).

The oxydase reaction was generally negative and the peroxydase

1) Krause, R. '23: Mikroskopische Anatomie der Wirbeltiere in Einzeldarstellungen IV. s. 678.

reaction was also negative except in the case of red blood-corpuscles.

The microscopical observation showed the number of red blood-corpuscles in eels to be from 2,546,000 to 2,855,000 as the individuals varied in weight from 170,00 to 0,78 grams; the number in the small eels being comparatively greater than in the large ones.

The number of white blood-corpuscles ranged from 2,300 to 4,200 in these same eels and therefore the ratio of the number of red and white corpuscles in eels was shown to be eight to one, while Harris (*op. cit.*) showed the ratio to be ten to one in the case of the skate.

Plate I. Explanation.

Showing the blood corpuscles of eel.
Nos. 4, 5, 6, 7....show erythrocytes in the fresh materials.
4, 5....viewed *en face* 6, 7....side view
Nos. 1-3, 8-23....stained with May-Grünwald staining.
1-3....erythrocytes.
8-12....lymphocytes, 8-9....small lymphocytes,
12....large lymphocyte.
11-12....contain Kurlow-like granules.
Nos. 13-16....neutrophil leucocytes.
Nos. 17-19....monocytes.
Nos. 20-23....thrombocytes.
Nos. 24-48....stained with May-Giemsa staining.
Nos. 24-31....lymphocytes.
Nos. 27-29, 31....contain Kurlow-like granules.
Nos. 30, 31....have lobed pseudopodia.
Nos. 32-35....neutrophil leucocytes containing numerous small stick-like granules.
Nos. 36-41....monocytes.
Nos. 42....may be a monocyte or a developing stage of neutrophil leucocyte.
Nos. 43....seems to be a lymphocyte but the granules could not be classified.
Nos. 44-48....thrombocytes.

A Biometric Study of Sexual Dimorphism in a Teleost, *Cololabis saira* (Brevoort)[1]

By

Itsuji Yasunari

(Received December 5 th, 1930.)

While at Minato, Ibaraki Prefecture my attention was called to a few slight but significant differences in the external characters of the two sexes of a bony fish, *Cololabis saira* (Brevoort). I undertook, therefore, a biometric study of sexual dimorphism in this fish at the suggestion of Professor Terao, to whom I am greatly indebted for his kind supervision during the course of my study. I also fully appreciate kindness of the staff of the Botanical and Physical Laboratories of our Institute given me in various ways.

The material on which the present paper is based was mostly obtained at the Tokyo fish market. It ranges from 30 to 35 cm in length, and three to five years in age, consisting of 65 males and 75 females. All the individuals were examined in a fresh condition; no alcoholic or formalin specimen was used. In passing it may be mentioned that the age of the fish is easily determined by the

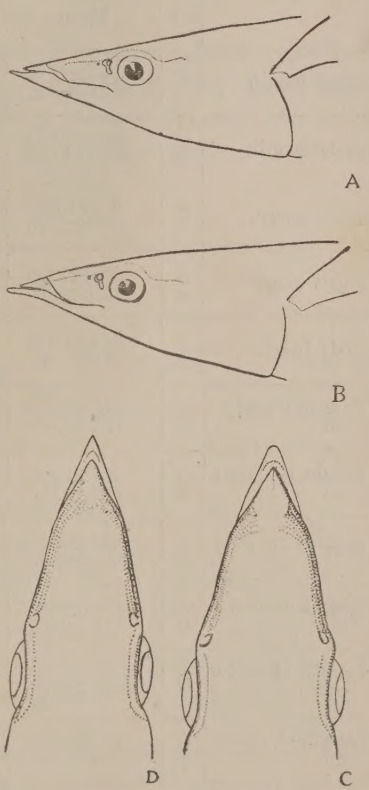

Fig. 1. Showing sexual dimorphism in *Cololabis saira*, $\times \frac{2}{3}$. *A*, side view of head of male; *B*, side view of head of female; *C*, dorsal view of head of male; *D*, dorsal view of head of female.

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 10. This report is a condensation of the thesis tendered partly to meet the requirements for the graduation from the Imperial Fisheries Institute, in which the original data are deposited.

number of annual rings found in the vertebrae, but it is wellnigh impossible by the examination of the scale and otolith.

The two sexes can be readily distinguished, when fresh from sea, by the colour of the tip of the lower lip: orange yellow in the male

Table 1. Biometric constants of *Cololabis saira*.

	Sex	Mean	Mode	Standard deviation	Coefficient of variation
Tatal length	♂	312.2±1.195	315.0	14.4±1 140	4.61±0.366
	♀	310.1±0.857	315.0	11.0±0.6 6	3.55±0.196
Body length	♂	282.3±1.084	272.5	13.255±1.049	4.62±0.366
	♀	279.4±1.050	277.5	10.303±0.554	3.69±0.203
Head length	♂	58.0±0.558	57.0	6.67±0.366	10.50±0.813
	♀	55.8±0.372	56.0	4.78±0.263	8.56±0.475
Snout length	♂	22.8±0.105	22.0	1.258±0.100	5.51±0.440
	♀	22.6±0.093	22.0	1.192±0.066	5.23±0.289
Body height	♂	34.4±0.255	35.0	2.03±0.161	5.90±0.469
	♀	35.5±0.167	35.0	2.16±0.118	6.06±0.335
Base of dorsal fin	♂	24.3±0.183	23.5	2.193±0.174	9.02±0.720
	♀	27.1±0.290	21.5	3.728±0.163	13.755±0.772
Height of dorsal fin	♂	14.7±0.127	14.5	1.517±0.120	10.311±0.826
	♀	14.8±0.096	14.5	1.348±0.074	12.284±0.686
Base of anal fin	♂	26.7±0.120	26.5	2.05±0.122	15.77±0.963
	♀	26.3±0.173	25.5	2.22±0.122	8.44±0.469
Height of anal fin	♂	13.2±0.060	13.0	1.241±0.074	9.40±0.565
	♀	13.3±0.081	13.0	1.044±0.058	7.85±0.435
Length of pectoral fin	♂	18.08±0.088	18.0	1.050±0.083	5.87±0.466
	♀	18.56±0.090	19.0	1.157±0.064	6.23±0.344
Length of ventral fin	♂	16.4±0.083	16.0	0.995±0.079	6.07±0.486
	♀	16.4±0.062	16.0	0.790±0.044	4.80±0.264
Tail length	♂	30.5±0.255	30.0	3.05±0.241	10.00±0.800
	♀	30.4±0.060	30.0	3.93±0.216	12.93±0.723
Ratio of base to height of dorsal fin	♂	0.626±0.005	0.625	0.0638±0.0051	10.92±0.855
	♀	0.615±0.006	0.625	0.0766±0.0042	12.46±0.681
Ratio of base to height of anal fin	♂	0.496±0.004	0.475	0.047±0.0037	9.47±0.756
	♀	0.517±0.004	0.525	0.048±0.0026	9.66±0.537

whereas olive green in the female. But these colours soon change to a dirty yellow in both sexes. Several invariable differences in the shape of the body parts, on the other hand, exist in the two. The tip of the lower lip is obtusely rounded in the male (Fig. 1, *C*) but acutely pointed in the female (Fig. 1, *D*). The upper profile of the head is nearly straight in the male (Fig. 1, *A*) but a little convex in the female (Fig. 1, *B*). The naked-eye examination is, however, more or less difficult to reveal the sexual differences in the measurements which were studied statistically with the results listed in Table 1.

The mean total length and body length are decidedly greater in the male than in the female as shown in Table 1. The head length, body height, base of dorsal fin, length of pectoral fin, and the ratio of base to height of anal fin on average show larger values in the female than in the male.

Table 2. Correlation coefficients of various characters of *Cololabis saira*.

Correlated characters	♂	♀
Total length and head length	0.0797±0.0831	0.1150±0.0769
„ „ „ snout „	0.2283±0.0794	0.2385±0.0735
„ „ „ tail „	0.1607±0.0815	0.1455±0.0762
Body length and body height	0.1987±0.0815	0.2062±0.0746
„ „ „ head length	0.0969±0.0829	0.1184±0.0768
„ „ „ snout „	0.2462±0.0786	0.2797±0.0718
„ „ „ base of dorsal fin	0.1850±0.0808	0.1334±0.0765
„ „ „ „ „ anal „	0.1876±0.0813	0.1705±0.0756
„ „ „ tail length	0.1235±0.0824	0.1234±0.0767
Head length and snout length	0.5171±0.0613	0.3466±0.0685
„ „ „ tail „	0.1776±0.0810	0.1801±0.0754
Base of dorsal fin & that of anal fin	0.4614±0.0659	0.7572±0.0532

Table 2 tabulates the correlation coefficients of various characters of the present species and shows that significantly higher correlation exists in the male between the length of head and that of snout but a greater value of the coefficient is obtained with the opposite sex between the base of dorsal fin and that of anal fin.

Buccal Incubation in the Percoid Fish, *Apogon lineatus* T. & S.[1]

By

Kiyomatsu Sakamoto.

(Received December 5th, 1930.)

The habit of the male of the fishes belonging to the family of Apogonidae to carry the ova and very young in his mouth has been found more or less general in this group. Of twelve species of this family inhabiting the waters of Japan two have been known to use this method, viz., *Apogon notatus* (Houttuyn)[2] and *A. lineatus*[3] T. & S. In putting the oral gestation of the second species on record, however, Tanaka was not sure of the sex of his three specimens. In my collection of fishes made in Toyama Bay in August, 1930 six individuals were found referrable to this species. They are: four females and one young male which have no egg in the mouth, and one adult male carrying a dense mass of the ova in the buccal cavity.

The author wishes to express his indebtedness to Professor Terao for his encouragement in execution of a study of this adult male specimen.

The specimen (Fig. 1, A) measures 56 mm in standard length. The isthmus is greatly swollen, the mouth wide open, and a small portion of the egg-mass a little projecting beyond the lips. The color of the ova in formalin is lemon yellow, their size varying 65 to 75μ in diameter. When examined under the microscope, the eggs (Fig. 1, B) are found united with each other by gluey thread-like substance which overlays the chorion. On dissection the buccal cavity is found jammed with the egg-mass; the individual eggs are, however, not so much crowded together so that there are enough interspaces left to allow the water-current to pass through for supplying oxygen. Futhermore, a considerable number of isolated ova are contained in the otherwise

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 13.

2) Fowler, H. W. and B. A. Bean. The fishes of the families Amiidae, Chandidae, Duleidae, and Serranidae, obtained by the U. S. Bureau of Fisheries steamer "Albatross" in 1907 to 1910, chiefly in the Philippine Is. and adjacent seas. U. S. Nat. Mus. Bull 100, vol. 10, 1930 (with three figures illustrating buccal incubation).

3) Tanaka, S. Buccal incubation in *Amia lineata*. Zool. Mag. (Dobuts. Zass.) **27** (323): 501-502, 1915 (in Japnese).

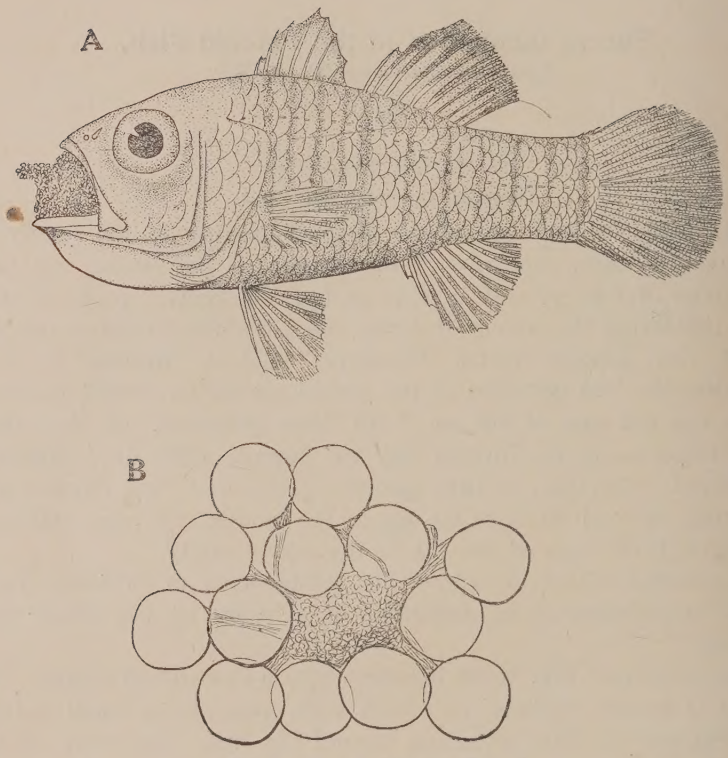

Fig. I *Apogon lineatus* T. & S.
A, male specimen with egg-mass in the buccal cavity, $\times \frac{4}{3}$;
B, a small portion of egg-mass united with thread-like substance, $\times 20$.

empty stomach, but quite intact in it, a feature showing their accidental inclusion in the digestive organ when the fish was disturbed by fishing. The incubating male was very thin, much thinner than the females and the younger male owing to long-continued starvation.

Report on the Biological Survey of the Tateyama Bay
1. Description of a New Wrasse-fish, *Cymolutes tateyamaensis*, n. sp.[1]

By

Kiyomatsu Sakamoto.

(Received December 5th, 1930.)

It is with great pleasure the present author takes this opportunity of expressing his warmest gratitude to Professor Terao for his kind supervision during the course of his study. His hearty thanks are also due to Asst. Professor Tanaka, of the Tokyo Imperial University, for kindly giving him access to some important literature.

In the description the length of the head is measured from tip of snout to posterior border of opercular flap. The length of the snout is the distance between the tip of upper jaw and the anterior edge of the orbit. The length of the body is measured from tip of snout to the base of caudal fin. The scales of the lateral series are counted to base of caudal rays, those on the fin not considered.

Cymolutes tateyamaensis, n. sp.

(New Japanese name: Tateyama-bera)

Head $3\frac{9}{10}$ in length; depth $3\frac{1}{10}$; depth of caudal peduncle $7\frac{3}{5}$; eye $4\frac{1}{5}$ in head; snout $2\frac{9}{10}$; interorbital space $7\frac{4}{5}$; D. IX, 12; A. II, 12; V. 1, 5; P. I, 11; scales in lateral series 80, 63 on superior, 17 on inferior, lateral line; between lateral line and insertion of dorsal 5; between lateral line and insertion of anal 30.

Body moderately elongate, notably compressed, caudal peduncle not so deep; dorsal contour ascending rapidly from tip of snout to the posterior portion of eye with a slight concavity in the middle of the snout and in the interorbital space as well; ventral outline very gently curved. Snout short, bluntly pointed, jaws subequal, lower lip a little

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 11. This forms the first of a series of papers intended for prompt publication on the biology of the Tateyama Bay, located south to the Tokyo Bay. Several members of the staff of our Zoological Laboratory have received a grant of research fund for executing this survey from the Department of Education of our government.—*A. Terao.*

longer than upper; lips thin. Teeth in a single row laterally, closely apposed and coalesced at base, growing gradually larger toward the tip of snout; an outer row represented by two strong canines on the anterior border of each jaw, the upper canines much larger than the lower; no posterior canines present. Pseudobranchiae well developed; gill rakers short, weak and pointed, 13 on anterior and 7 on posterior border of first arch. Eyes nearer to tip of snout than to edge of opercle. Edge of opercle and preopercle smooth, opercle with a large flap, longer than horizontal diameter of eye.

Lateral line interupted under dorsal seventh soft ray. Body covered with very small scales. Scales not forming a sheath at base of fins; those at root of caudal a little larger than those at any other portions. Opercle and cheek naked.

Memberane of dorsal not incised, of short, weak, and slender spines,

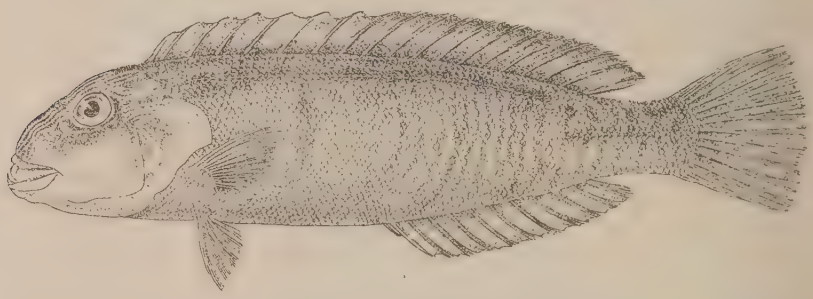

Fig. 1. *Cymolutes tateyamaensis*, n. sp. ♀. × $1\frac{1}{3}$

the first two scarcely visible to the naked eye, the longest $3\frac{1}{2}$ in head; the longest ray $2\frac{4}{5}$. Anal spines very short and weak, the second about $5\frac{1}{5}$ in head; the longest ray 2. Dorsal and anal rays when depressed not reaching base of caudal. Caudal truncate, $1\frac{7}{10}$ in head; pectoral 2 in head; ventral $2\frac{3}{10}$. Fin-memberanes thin, transparent.

Color in formalin grayish brown, darker above, lighter below; a series of irregularly arching dark brown bands cross posterior part of trunk, the first very faint one just above the anal opening; a longitudinal dark brown band runs along each of superior and inferior lateral lines, uniting the series of the cross bands. A dark brown cross band of considerable width is also seen below the first dorsal ray.

Short parallel striations extend from eye to posterior border of upper

part of opercle, the lowest one giving off posteriorly several ascending branches. Striations are also seen running from the insertion of dorsal spine convergently toward the tip of snout.

Described from a female specimen, 70 mm. long, collected from the Tateyama Bay, depth unknown. The type is deposited in the Zoological Laboratory, Imperial Fisheries Institute, Tokyo.

This species is closely allied to *Cymolutes praetextatus* Günther but differs from it principally in color, in number of scales of lateral series and that of pectoral spine and rays, and in presence of striations on the differently proportioned head. It is worth while to note that the genus *Cymolutes* is new to the fauna of Japan since it has hitherto been known to occur exclusively in the Indian Ocean.

Two New Species of Fishes from the Japan Sea.[1]

By

Kiyomatsu Sakamoto.

(Received December 5th, 1930.)

The two species here described under the names of *Stichaeus elongatus* and *Malacocottus gibber* are each based on a specimen obtained in August, 1930 in Toyama Bay by a danish seine that had been down to a depth of about 150 meters. They were preserved in formalin while fresh from sea and carefully studied afterwards under the direction of Professor Terao to whom my hearty thanks are due. I am also much indebted to Professor Amemiya and Asst. Professor Tanaka, of the Tokyo Imperial University, for help kindly rendered.

Stichaeus elongatus, n. sp.

(New Japanese name: Nuimemodoki)

Dorsal LII; anal I, 42; ventral 4; pectoral 14.

Head $4\frac{1}{5}$ in length; depth 9. Depth of caudal peduncle 4 in head; snout $5\frac{9}{10}$; eye $6\frac{2}{5}$; interorbital space $17\frac{3}{10}$.

Body elongate, compressed, head rather large, depressed and pointed. Eye large, at extreme upper profile of head, directed obliquely upward; interorbital space concave, narrow, $17\frac{3}{10}$ in head. Snout pointed, its upper profile almost straight to the supraoccipital region. Lower jaw projecting beyond the upper. Maxillary reaching to below posterior margin of eye. Teeth very small, not so sharp, in narrow bands on both jaws; tip of lower jaw with 2 canines; vomer with wide bands of villiform teeth, palatines with narrow bands of the same. Membrane of gill-opening forming a very narrow V-shaped free fold across the isthmus. Psendobranchiae large; gill rakers on first arch about 3+10, short, flat and blunt. Nostrils with small tubes. No dermal filament on head.

Body covered with very smooth scales; head, membrane of dorsal, and base of caudal naked. Lateral line simple, extending from upper edge of gill-opening to the dorsal spine nineth from the last along upper part of body, the pores in 2 rows.

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 12.

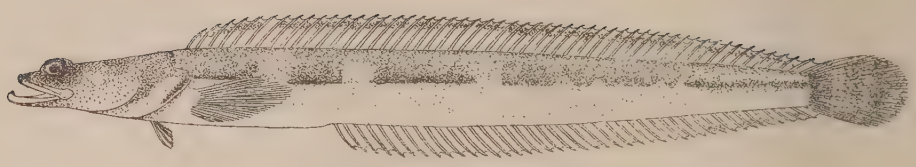

Fig. 1. *Stichaeus elongatus*, n. sp. $\times\frac{4}{3}$. ♀

Dorsal inserted posterior to above gill-opening, not united with caudal; the spines stiff, pungent, the middle ones contained about 5 times in head; membrane of the fin not thickened, not incised between the spines. Anal inserted below thirteenth dorsal spine, the membrane thin, not incised between the rays; middle rays $4\frac{1}{5}$ in head. Caudal slightly convex, $1\frac{1}{2}$ in head. Pectoral rounded, the lower rays shorter than the upper; length of fin contained $1\frac{1}{2}$ times in head. Ventrals pointed, $3\frac{1}{10}$ in head.

Color in formalin grayish brown on back, abruptly changing to lighter color at middle of sides; a very narrow, irregularly interrupted, dark gray band running along middle of sides; vermiculated faint cross bands densely crowded above the middle band; a shorter, narrow dark grayish brown band extending along near the distal margin of opercular flaps. Dorsal white and transparent with a narrow brawnish broken band running near its margin. Anal, pectorals and ventrals are white without bands or blotches. Caudal with three dark gray cross bands.

Described from a female specimen 83 mm. long from Toyama Bay. Type in the Zoological Laboratory, Imperial Fisheries Institute, Tokyo.

This species is distinguished from another Japanese species of this genus, *S. nozawae*, in having slenderer body, longer head, narrower interorbital space, more spines in the dorsal and anal, hinder insertion of dorsal, and in having interrupted dark gray middle band. The present species is closely allied to *S. punctatus* (Fabricius), but differs from it in having slenderer body, shorter snout, and more spines in the dorsal and anal; lateral line extending more posteriorly, ending abruptly at about $\frac{19}{20}$ the length of body.

Malacocottus gibber, n. sp.

(New Japanese name: Seppari-kazika.)

Dorsal IX, 16; anal 13; ventral I, 3; pectoral 22.

Head 2 in body length except caudal; depth of head 3; width of head 3; depth $2\frac{9}{10}$; snout $6\frac{3}{5}$; tip of snout to insertion of dorsal $2\frac{1}{3}$; base of dorsal $1\frac{7}{10}$; base of anal $3\frac{9}{10}$; base of pectoral $4\frac{9}{10}$; length of caudal $3\frac{1}{5}$; eye $1\frac{1}{3}$ in snout; eye $4\frac{1}{3}$ in head; maxillary $2\frac{1}{10}$; snout $3\frac{2}{5}$; interorbital space $5\frac{2}{5}$; depth of caudal 6; length of pectoral $1\frac{9}{10}$; length of ventral $4\frac{1}{10}$; length of caudal $1\frac{3}{5}$.

Body very robust, tadpole-shaped, back much elevated, hump-shaped, tapering from insertion of soft dorsal; body scaleless, covered with a very thin, feeble, lax skin.

Fig. 2. *Malacocottus gibber*, n. sp. $\times\frac{1}{1}$ ♂

Head cuboid, its depth somewhat equal to that of width, with vertical cheeks; supraocular rim much elevated. Nine tubercles on head definitely placed: the largest one in front of interorbital space, 1 in front of each eyes, 2 in interorbital region, forming ridge-like transverse protuberances, a similar one on suborbital region, 1 on temporal region; a large, somewhat trifid one on posterior portion of temporal, a smaller simple one between it and posterior angle of preopercle, and a larger one on occiput; nasal spine obsolete; eye large; supraocular rim much elevated, forming a wide shallow interorbital groove, its width $1\frac{3}{10}$ in diameter of eye; anterior portion of interorbital space greatly depressed; occiput somewhat depressed. Snout not so blunt, the anterior profile somewhat steep from tip to anterior interorbital tubercle;

mouth large, oblique, the maxillary reaching to below the middle of pupil; lower jaw included; villiform teeth in wide bands on jaws; none on vomer and palatines; gill-opening very wide, its width $1\frac{3}{5}$ in head, gill membrane broadly united to the isthmus; gills $3\frac{1}{2}$; no slit behind last gill arch; gill rakers blunt, tubercular, each with about 10 short, filamentous cirri on the top, 19+0 on first arch.

Preopercle with three long, simple spines, upper one stronger, sharp, directed obliquely upward; second spine longest, slender, straight or with a scarcely perceptible upward curve; third spine shorter and weaker, directed vertically downward, entirely concealed beneath the thin, lax integument, all the other spines more or less concealed. No flap on head. Pores scattered on top and sides of head, distinct four pores on a straight line between anterior nasal pores. Posterior nostril in short tube, anterior one non-tubular, larger. Lateral line in an arching curve, concurrent witn back, extending to below the sixth soft dorsal, thence passing into a shorter straight line which runs along the middle of sides; the pores of lateral line about 16.

Dorsal fin two, the first begining over opercular angle, narrowly joined at base, a notch between them; the spinous dorsal very feeble and filamentous, undistinguishable from soft rays, hidden in the thin lax skin, only tips freely projecting from the membrane; soft dorsal very long, the longest $2\frac{4}{5}$ in head; anal shorter than dorsal; the free portion of caudal short, $5\frac{4}{5}$ in head, higher than wide; pectorals very long, somewhat pass the last dorsal spine, pectoral base very broad; ventrals short; caudal rounded.

Color in formalin light gray, under portion of soft dorsal darker, the head and body thickly sown with minute black pigment specks; there is no remarkable bar or blotch; all fins darker than the body except white ventrals.

This species may be principally distinguished from the hitherto known two species of this genus by the following characters:—

	M. zonurus	*M. kincaidi*	*M. gibber*
Dorsal fin.	IX, 14.	IX, 14.	IX, 16.
Anal fin.	11	11	13
Pores on lateral line.	14	15	16
Cirri on head.	present	reduced or obsolescent	absent
Accessory spine from the base of the middle preopercular spine	present	absent	absent
Dorsal profile of trunk	almost straight	almost straight	hump-backed

Type is a male 140 mm. long, from Toyama Bay, and preserved in the Zoological Laboratory, Imperial Fisheries Institute, Tokyo.

(*gibber*, hump-backed.)

Occurrence of the Nuptial Organ in the Female of the Salmonoid Fish, *Plecoglossus altivelis* T. & S.[1]

By

Ken-ichi Ebina.

(Received December 5th, 1930.)

Since the publication of my paper[2] on the nuptial organ which is characteristic to the spawning male of the salmonoid fish, *Plecoglossus altivelis* T. & S., I had opportunity to examine seven male and six female specimens of the same species caught during the breeding season and have found the organ in question not only in the males but also in the females. The nuptial organ of the females, however, differs from that of the males in several particulars which are given in the present paper. It is my pleasant duty to return herewith my hearty thanks to Professor Terao for his kind supervision during the course of my study.

The specimens were obtained by Professor Higurashi on Nov. 18, 1927 in the Tama River which flows into the Tokyo Bay. They were preserved in formalin in a good condition and were placed at my disposal by Professor Higurashi, to whom I am much indebted for his kindness. No comment is here needed on the nuptial organ of the male individuals since it is constracted just the same as described before (*op. cit.*). Remarkably enough, a greater variability in the extent of distribution of this tissue-complex is found in the females than in the males, probably due to its extremely short duration during the season. Of the six females under my examination, varying 90—162 mm. in length, a speciemen, 125 mm. long, is furnished with the organs in the widest distribution. This individual (Fig. 1, *A*) has six organs scattered in front of eye and also the same number of them dispersed just above the upper jaw. A linear series of six organs are present on each jaw, but none from the tip of snout to the parietal region of head. These integumentary protuberances (*nup.*) are compactly set on the scales (Fig. 1, *B*) which form several rows along the dorsal side of trunk, extending from its anterior end to caudal peduncle, and also along the ventral side, above ventral fin to caudal peduncle (Fig. 1, *A*). All the

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 14.

2) Ebina, K. Nuptial organ of the salmonoid fish, *Plecoglossus altivelis* T. & S. Jour. Imp. Fish. Insti., vol. XXV, No. 2, 1929.

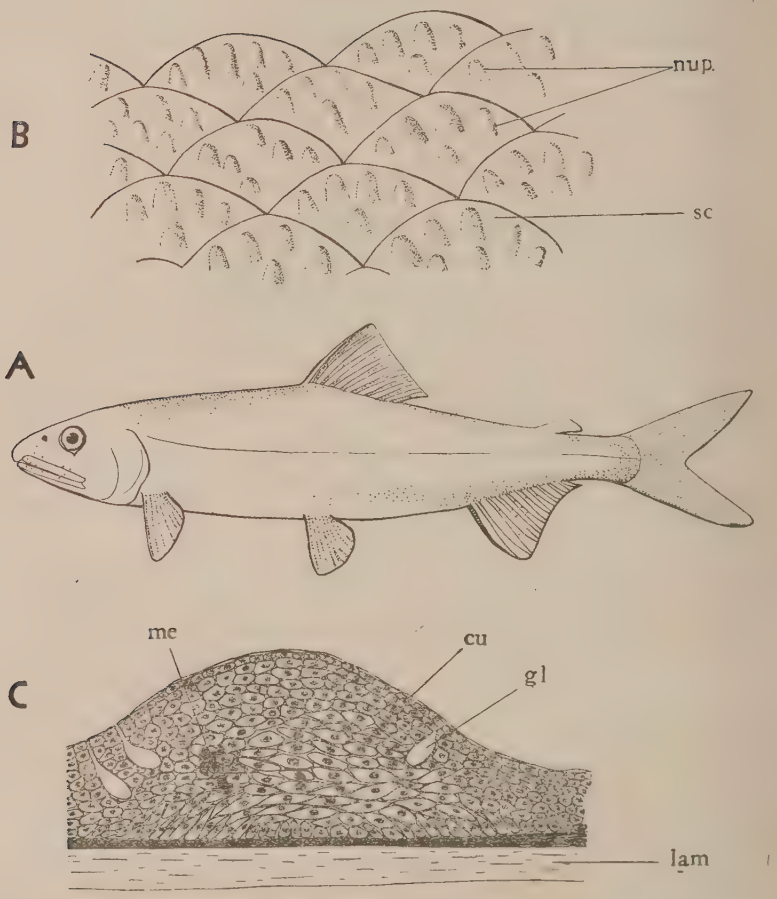

Fig. 1. Nuptial organ of the female of *Plecoglossus altivelis* T. & S.

A. Side view, stippled area representing the region covered with nuptial organ, $\times \frac{2}{3}$

B. Several scales of the dorsal side, ×18;
nup., nuptial organ; *sc.*, scale.

C. Median section through the nuptial organ on scale, ×356;
cu., cuticula; *gl.*, unicellular gland; *lam.*, scale lamella; *me.*, melanophore.

fins except the adispose fin have the organs arranged in one or two rows on the rays; the largest one is found on the anal fin-ray, measuring 0.2 mm. in diameter, whereas those on the scales are each about 0.1 mm. in diameter.

In section the organ is found to have a nearly similar structure as that of the male (Fig. 1, *C*). The characteristically very thin cuticular layer (*cu.*) overlays the whole structure. Beneath this layer are found two or three layers of cells which are mostly polygonal in outline, but sometimes more or less flattend. The middle part consists of flattend spindle-shaped cells, between which there exist rather wide lumina. The lower layer of the organ is composed of pyramidal cells which are separated from a sheet of melanophores by the basement membrane. Isolated melanophores (*me*) are present near the middle of the protuberance. The outermost cuticular layer is perforated by several knob-shaped unicellular glands (*gl.*).

It goes without saying that the organ in the female is essentially the same as that in the male in structure, and I do not hesitate to retain the term "nuptial organ" for this type of formation both in the male and the female in spite of criticism from various quarters on the coinage of the designation.

Life-History of the Water-flea, *Moina macrocopa* Strauss, Reproducing Parthenogenetically.[1]

By

Arata Terao and Tomozô Tanaka.

(Received December 5th, 1930.)

Inasmuch as Miss Noyes[2] has shown that uniform populations of the parthenogenetically reproducing rotifer, *Proales decipiens*, have almost equal duration of life, the question suggests itself whether or not this uniformity is due to that of genetic constitution consequent upon the parthenogenetic reproduction. It would not be, therefore, without interest to report here on the life-history of the water-flea, *Moina macrocopa*, which reproduces in a similar way.

The data given in this paper are partly taken from the unpublished records of the already reported experiment on the influence of temperature upon the duration of life[3], and partly from those of a second experiment on the mortality of the water-flea at 27°C. All the individuals tested in the first series of the experiments were descended from clones which had been originated by a single parthenogenetically reproducing mother. The experimental animals which were of zero age were put one in each of vials measuring 3 × 6 cm with 25 c.c. of culture-medium which consisted of one part of Jennings and Lynch's solution of oat-meal for rearing the rotifer[4] and two parts of rain water which contained a large number of *Scenedesmus*. These vials were kept as stated elsewhere (*op. cit.*) in compartments of a Senô-Tauti serial incubator which ran at 5°, 9°, 15°, 21°, 27°, and 33°C. respectively.[5] The observations were taken once a day followed by change of the culture-medium. The reserve mass was maintained in a good condition at 27°C until the second

1) Contributions from the Zoological Laboratory, Imperial Fisheries Institute, No. 15.

2) Noyes, B. Experimental studies on the life history of a rotifer reproducing parthenogenetically (*Proales decipiens*). Jour. Exp. Zool. 35 : 225–255, 1922.

3) Terao, A. and T. Tanaka. Duration of life of the water-flea, *Moina macrocopa* Strauss, in relation to temperature. Jour. Imp. Fish. Inst., 25 (3): 67, 1930.

4) Jennings, H. S. and Ruth S. Lynch. Age, mortality, fertility, and individual diversities in the rotifer Proales sordida Gosse. II. Life history in relation to mortality and fecundity. Jour. Exp. Zool. 51 (3): 339–381. 20 fig. 1928.

5) We fully appreciate the help rendered to us by the staff of the Physical Laboratory in the regulation of the apparatus.

Table 1. Deaths observed in respective populations of *Moina macrocopa*.

Age intervals in days	Temperature (C)						
	5°	9°	15°	21°	27° (1st exp.)	27° (2nd exp.)	33°
0—1	7					5	
1—2	23	4				75	1
2—3	19	13			2	95	2
3—4	5	3	5	7	7	53	31
4—5	13	6	5	4	8	15	49
5—6	10	6	3	5	25	19	29
6—7	20	12	7	13	25	20	21
7—8	5	15	5	8	22	25	2
8—9	8	11	3	15	13	11	
9—10	1	7	4	12	3	11	
10—11		2	3	16	2	13	
11—12		5	3	16	0	11	
12—13		5	3	6	0	12	
13—14		0	4	3	1	14	
14—15		4	4	1		16	
15—16		5	10	2		9	
16—17		0	19	0		4	
17—18		2	7	3		1	
18—19		1	6	1		1	
19—20		1	6				
20—21		3	5				
21—22		2	2				
22—23		1	3				
23—24		1	2				
24—25		1	3				
25—26		1	2				
26—27		0	0				
27—28		1	0				
28—29		1	0				
29—30		0	0				
30—31		1	0				
31—32		1	0				
32—33		0	0				
33—34		1	1				
34—35		1					

experiment which was executed in exactly the same manner as in the first except that all the vials containing experimental animals one in each were kept at 27°C. Table 1 contains the results of our experiments.

It is clear that there exist great diversities in the duration of life in each series tested, and that more than half of each population die before the half of the maximum life span incidental to each group is peached. These facts seem to point to the conclusions that uniformity of the duration of life as observed in the rotifer is one of the characteristics of this form and that even when a parthenogenetically reproduced ropulation of some other species is kept under a uniform environment the duration of life of each individual of this population may vary greatly. Another paper will deal with a comparison of the mortality of *Moina* with that of other organisms.

Beiträge zur Entwickelungsgeschichte von Encoeliaceen.

Von

S. Ueda.

mit Tafel II und III.

Einleitung.

Wie wohl bekannt, gibt es bei den Phaeosporeen zwei Arten von Sporangien: unilokuläre und plurilokuläre. Die ersten sind im allgemeinen für Zoosporangien, die letzteren für Gametangien gehalten. Bezüglich der Encoeliaceen herrscht jedoch noch grosser Zweifel über diese Einteilung. So ist von Thuret (1851), Reinke (1878) und Yendo (1919) die Kopulation der Schwärmer aus den plurilokulären Sporangien verneint worden. Wenn Berthold (1881) und Kuckuck (1898) auch eine geschlechtliche Natur für die in plurilokulären Sporangien entwickelten Schwärmer von *Scytosiphon* beobachteten, so fanden sie doch nur wenige Fälle von Kopulation derselben, dagegen eine grosse Anzahl von parthenogenetischen Keimungen. In den Meeren von Mittel-Japan treten die meisten Encoeliaceen im späten Herbst auf und entwickeln sich weiter während des Winters, um gegen Ende des Frühjahrs zu verschwinden.

Mir stellt sich also ein zweifaches Forschungsziel vor: einerseits, die Natur der in den plurilokulären Sporangien dieser Pflanzen entwickelten Schwärmer zu bestimmen, und anderseits, die Entwickelungsgeschichte der keimenden Schwärmer zu verfolgen.

Die Untersuchung wurde in Jahre 1927 angefangen und bis 1930 fortgesetzt, indem ich die Kulturen der Schwärmer von *Punctaria*, *Scytosiphon*, *Endarachne* jährlich von Februar bis Mai wiederholte. Den Herren Professoren Dr. K. Miyake und Dr. K. Okamura sage ich für ihre freundliche Leitung der Arbeit meinen verbindlichsten Dank.

Kulturmethode.

Bei meinen Kulturversuchen habe ich hauptsächlich *Punctaria* sp. gebraucht. Als Kulturgefässe benutzte ich Kristallisierschalen von etwa

400 ccm Inhalt mit zweimal filtriertem Meerwasser ohne Zusatz von Nährstoffen.

Das von mir kultivierte Material ist in der Kanazawa-Bucht in der Nähe von Yokohama gesammelt worden und war mit reifen sogenannten plurilokulären Sporangiensori reichlich versehen. Die als Kulturmaterial dienenden Thallusteile der Pflanzen wurden von epiphytischen Mikroorganismen möglichst gereinigt, sorgfältig abgeschnitten, dann in die mit Meerwasser gefüllten Kulturgefässe gestellt und darin stundenlang stehen gelassen, sodass die Schwärmer heraustreten konnten. Das Kulturwasser war von der grossen Menge derselben bräunlich gefärbt. Zur Erhaltung reiner Kulturen wurde dann der dicht schwärmerhaltige Teil des Wassers mit einer Pipette in mehrere Kulturschalen gebracht, und die mit Glasscheiben bedeckten Gefässe am Nordfenster des Laboratoriums stehen gelassen.

Dazu habe ich gleichzeitig auch einige Kulturversuche mit *Scytosiphon lomentarius* (Lyngb.) J. Ag. und mit *Endarachne Binghamiae* J. Ag. gemacht und ähnliche Ergebnisse wie im Versuch mit *Punctaria* sp. erhalten.

Ergebnisse.

Trotz meiner vieljährigen Bemühungen konnte ich doch bisher keinen Kopulationsakt zwischen Schwärmern aus den allgemein für plurilokuläre gehaltenen Sporangien konstatieren. Die Schwärmer sind birnförmig, etwa 5 μ breit, 7–8 μ lang, mit zwei zilien versehen und besitzen je einen Chromatophoren mit einem roten Augenfleck.

Die aus den Sporangien ausgetretenen Schwärmer (Taf. II. Fig. 3. a.) bewegen sich anfangs mit grosser Schnelligkeit, schliesslich aber kommen sie am Rande des Gefässes oder an der Oberfläche des Wassers zur Ruhe, runden sich ab und umgeben sich mit einer Zellhaut. Nach ein oder zwei Tagen beginnen sie zu keinen (Taf. II. Fig. 3. b.), und bald bemerken wir die erste Querwand. Vor der Zellteilung teilen sich zuerst der Kern und der Chromatophor je in zwei Teile, dann erscheint dazwischen eine Querwand, sodass jede von den beiden neugebildeten Zellen einen Kern und einen Chromatophoren enthält. Nach etwa 7 Tagen entwickeln sich die Keimlinge zu monosiphonen Zellfäden (Taf. II. Fig. 4.), die aus etwa 7–8 Zellen bestehen. Diese wachsen weiter und weiter, doch nicht zu normalen Pflanzen aus, sondern bilden im Verlauf von etwa vier Wochen kriechende, verzweigte, *Streblonema-*

ähnliche fadenartige Fronden (Taf. II. Fig. 5. a. b. c.), die jedoch in weiteren zwei oder drei Wochen nur eine geringe Grösse erlangen. Sie zeigen dann 0,5 mm—1 mm hohe Büschel, worin ich eine grosse Menge von frisch gebildeten echten plurilokulären Sporangien (Taf. II. Fig. 6. und Taf. III. Fig. 1.) bemerken konnte.

Die sich auf den fadenartigen Fronden befindenden plurilokulären Sporangien haben eine ähnliche Gestalt, wie man bei den Ectocarpaceen findet; und die daraus hervorgegangenen Schwärmer (Taf. III, Fig. 1. c.) besitzen fast dieselbe Grösse und Organisation, wie die der ersten Kulturen. Diese neuen Schwärmer zeigen sehr häufig eine geschlechtliche Natur, erscheinen also als echte Gameten. Ich muss zwar bemerken, dass ich keine direkte Kopulation zwischen ihnen erblicken kann, doch treffe ich eine grosse Menge solcher an, die in Ruhe gekommen und demnach als Zygoten (Taf. III. Fig. 1. e.) anzusehen sind. Dazu kann ich feststellen, dass sie doppelt so gross als die einzeln vorkommenden sind und zwei rote Augenflecken und zwei Chromatophoren tragen. Leider gelang es mir nicht, die Weiterentwicklung der Zygoten in meinen Kulturgefässen zu verfolgen, da dieselben trotz der sorgfältigsten Behandlung durch Mengen von ungeladenen Mikroorganismen, wie Diatomen und Infuzorien, in ihrem Wachstum gehindert wurden.

Schluss.

Obige Ergebnisse gestatten mir, die folgenden Schlüsse zu wagen. Nach meiner eigenen Beobachtung sowie nach der von Thuret, Reinke und Yendo geschah niemals eine einzige Kopulation der Schwärmer aus den sogenannten plurilokulären Sporangien. Die Kopulation fand ich ja ausschliesslich zwischen den Schwärmern aus den echten plurilokulären Sporangien, die sich auf den aus den Schwärmern von normalen Pflanzen entwickelten Adelophykoidenpflanzen gebildet haben.

Die Pflanzen sollen während des Sommers unter einem mikroskopischen Zustand bleiben, und die normalen Formen, die sich im kommenden Winter entwickeln, sollen aus den Schwärmern, der auf diesen fadenartigen Pflanzen gebildeten Sporangien herauskommen. Ähnliche Tatsachen sind schon von Angst (1926), Sauvageau (1922, 1926, 1927, 1929) and Setchell (1925) u.a. bei *Soranthera ulvoidea*, *Carpomitra cabrerae* Kuetz., *Dictyosiphon* sp., *Asperococcus* sp., *Castagnea zosterae* Thur. und *Leathesia* sp., beobachtet worden.

Es ist allerdinge merkwürdig, dass *Punctaria* wärend ihres Lebens,

sowohl in der delophykoiden (makroskopischen) als auch in der adelophykoiden (mikroskopischen) Periode, immer dieselben Arten von Sporangien bildet. So erlaube ich mir anzunehmen, dass die sogenannten plurilokulären sporangien auf den normalen, d. h. makroskopischen Fronden in Wirklichkeit nichts anders als die unilokulären sind, denn einerseits findet man darin keine wirkliche Trennungswand nach der Entleerung der Schwärmer, und anderseits konstatiert man bei denselben den Mangel an geschlechtlicher Natur.

Einige Forscher behaupten wohl, dass diese Pflanzen zugleich unilokuläre Sporangien haben, doch glaube ich, dass diese unilokulären Sporangien nichts anders als sogenannte plurilokuläre in ihrem anomalen oder unreifen Zustand sind.

Aus meinen Versuchen möchte ich erschlissen, dass Encoeliaceen unter dem delophykoiden Zustand nur dem Schein nach plurilokuläre, in Wirklichkeit aber unilokuläre Sporangien haben, während sie unter dem adelophykoiden echte plurilokuläre Sporangien tragen, die zwar bisher kaum jemand erwähnt hat. Es wurden ja auch neulich von den schon genannten Autoren ähnliche Beispiele unter den obigen Pflanzenarten beobachtet.

Tokio Oktober, 1930.
Fischerei-Institut.

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Figuren-Erklärung.

Tafel II.

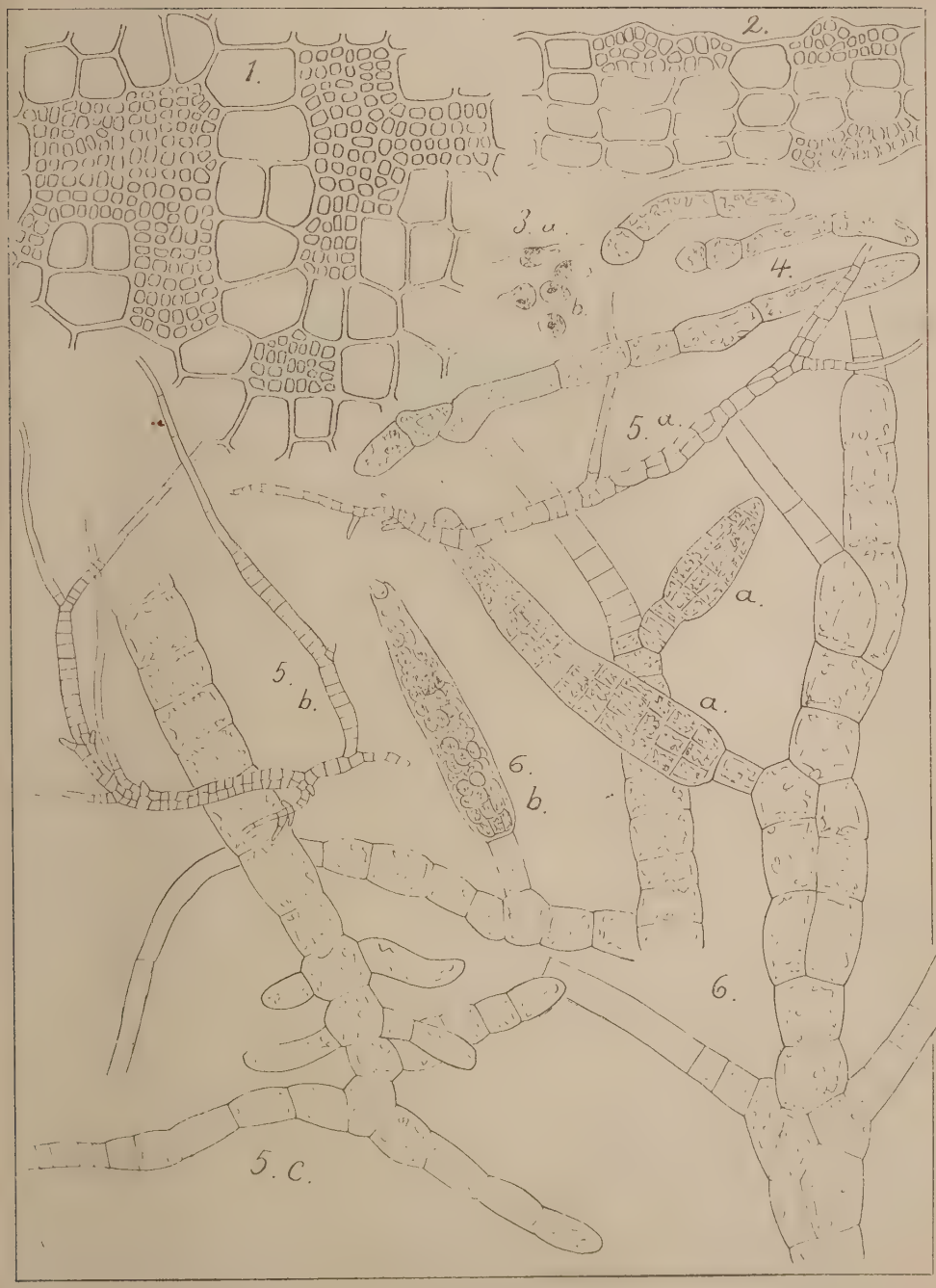
Punctaria sp.

1. Thallusteil von der Fläche mit sogenannten plurilokulären Sporangien. ×465.
2. Querschnitt eines Thallus mit sogenannten plurilokulären Sporangien. ×465.
3. a) Schwärmer; b) Keimende Schwärmsporen. ×500.
4. Entwicklung der Keimlinge (3–7 zelliges Stadium). ×500.
5. a) und b) Etwa vier Wochen alte fadenartige Keimpflänzchen. ×100.
   c) Basalstück eines Keimpflänzchens. ×500.
6. Zweigstücke des Keimpflänzchens mit echten plurilokulären Sporangien:
   a) Junge Sporangien; b) Dasselbe im reifen Zustand. ×500.

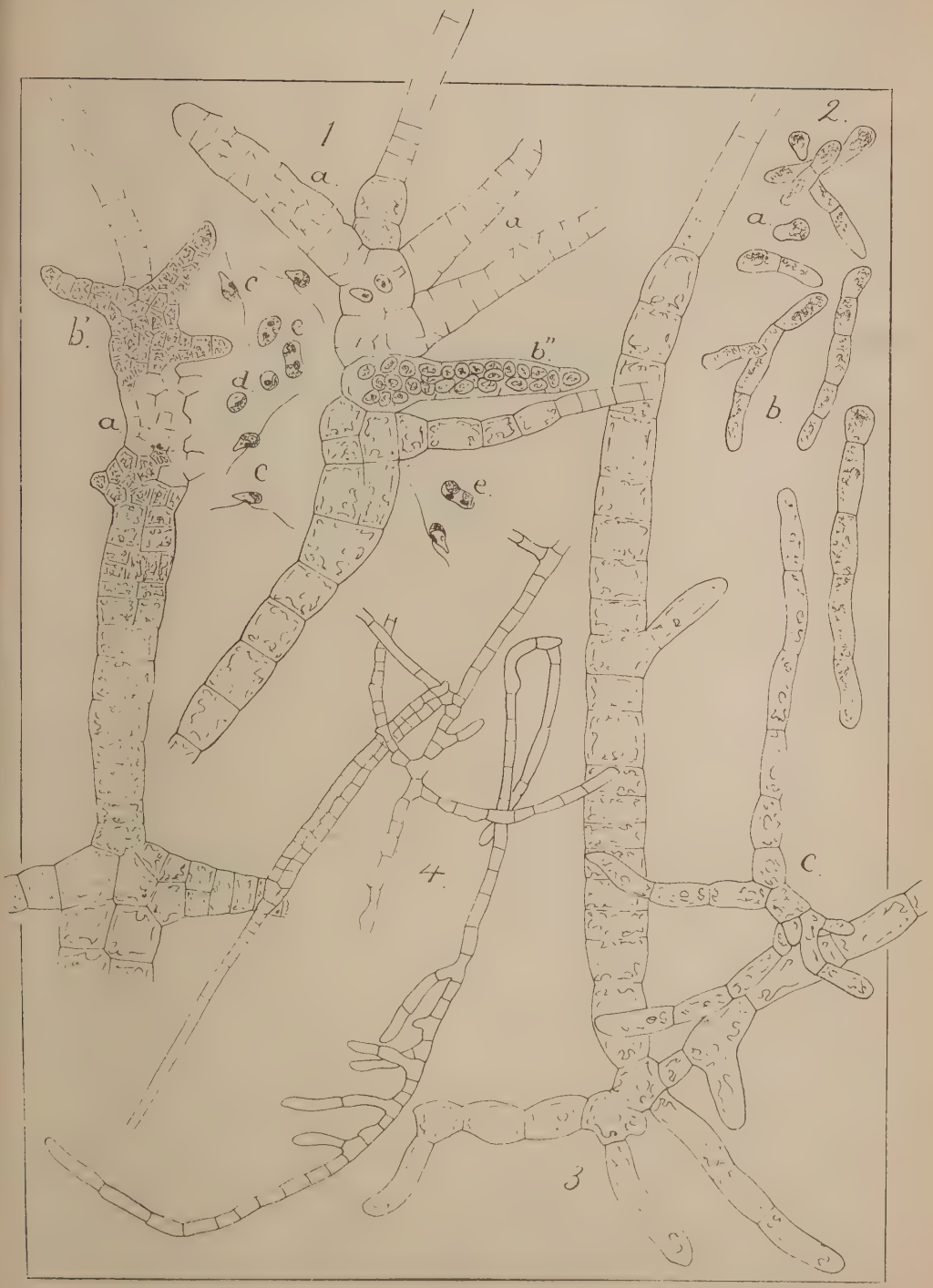
Tafel III.

1. *Punctaria* sp. 2–4. *Scytosiphon lomentarius* (Lyngb.) J. Ag.

1. Zweigstücke der fadenartigen Pflänzchen mit interkalaren plurilokulären Sporangien; die Sporangien im Teile (a) entleert; daneben Schwärmer (c); b′) unreife Sporangienteile; b″) reifer Teil des Sporangiums, ebenfalls in der Entleerung; d) Schwärmsporen im Ruhezustand; e Zygoten. ×500.
2. a), b) and c) Entwicklungsstufen der Keimpflänzchen. ×245.
3. Zweigstücke eines Keimpflänzchens. ×500.
4. Weiter Entwicklungszustand der fadenartigen Keimpflänzchen. ×100.



Punctaria sp.



1. *Punctaria* sp.

2–4. *Scytosiphon lomentarius* (Lyngb.) J. Ag.

A few Studies on Determination of Nitrogen.

By

W. Shimidzu.

(Received December 5th, 1930.)

When we have often to determine a large number of sample, it is very troublesome to depend on the old method of the nitrogen determination. To save these troubles, a new apparatus which depends on the principle of Pregl's method (Die quantitative org. Mikroanalyse, S. 113–116, 1923) is designed.

In this apparatus, ammonia is drived away by means of steam, and, at the end of the operation, the cock of steam is closed, and the liquor is thrown away by means of the adverse stream. Steam in this apparatus has three useful services, that is——,

(1) it agitates the liquor (it takes place of Zinc),

(2) it removes the liquor to the outside, when the experiment is completed,

(3) it distil out ammonia promptly under the same reason as of the steam distillation.

On the practical application of this apparatus, the experimental time shall be shortened by half, compared with that of the old method.

The experimental results is shown in the table I and II. The greater parts of ammonia is distilled in the beginning short time. And, the distillating velocity may certainly be varied with the force of fire and the volume of the sample, but commonly, a half of the total nitrogen is distilled out in the first certain distillate or time, and $\frac{1}{2}$ of the residual nitrogen, namely, $\frac{3}{4}$ of the total nitrogen is distilled in the second same volume or time. In other words, this distillation shall be operated almost likely in a form of the infinite geometrical progression with the common ratio of $\frac{1}{2}$. The rate of the residual nitrogen in the flask is worked out by means of a mathematical formula,

$$x=\frac{m}{2^n}$$

where, x=nitrogen residued in the flask,
m=the total amount of nitrogen,

$$n=\frac{S}{a}\left(\begin{array}{l}S \text{ is the total volume of the distillate,}\\ a \text{ is the volume of the distillate required}\\ \text{to distil out the first } \frac{m}{2}\end{array}\right).$$

Therefore, the smaller m, the amount of nitrogen in the sample, the sooner is the distillating velocity. The velocity is also, of course, varied with the force of fire and the amount of the sample, but, if these conditions the restricted in such a degree that the distillate does not result to be warmed, the first period or volume which is required to distil out the first $\frac{m}{2}$, is 15 cc. for 300 cc. of the sample, and 20 cc. for 400 cc. of it. And yet, the time needed for distillation of a unit volume of the distillate is, generally speaking, invariable. It is, therefore, advisable to lessen the volume of the sample.

When the distillation depends only on the means of fire, without applying steam, it is required the same volume to distil out $\frac{m}{2}$, and, it is required two times of hours to distil out the same volume. In respect of the time for boiling, it requires twice as much as the steam distillation, therefore, the necessary time for steam distillation shall be halved in the whole experiment, as comparing with the former.

TABLE I.

The rate of the nitrogen distillation by means of the steam distillation.

(I) Taking 300 cc. of the sample ($a=15$)

Total nitrogen (m)	Volume of distillate (S)	Time for boiling.	Time for distillation.	Quantities of nitrogen distilled.	Residual nitrogen (x)	
					obs. (± 0.05)	cal.
mg.	cc.	′ ″	′ ″	mg.	mg.	mg.
5	15	2, 55	0, 46	2.5	2.5	2.5
〃	30	3, 05	1, 34	3.8	1.2	1.25
〃	45	2, 25	2, 17	4.4	0.6	0.63
〃	60	2, 25	3, 0	4.65	0.35	0.31
〃	75	2, 20	3, 42	4.8	0.2	0.16
〃	90	2, 33	4, 27	4.9	0.1	0.08
〃	105	2, 35	5, 19	4.59	0.05	0.04
〃	120	2, 30	5, 55	5.0	0.0	0.02
20	15	2, 30	0, 45	10.6	9.4	10.0
〃	30	2, 30	1, 30	15.3	4.7	5.0
〃	45	2, 20	2, 15	17.55	2.45	2.5
〃	60	2, 25	3, 0	18.75	1.25	1.25
〃	75	2, 15	3, 45	19.3	0.7	0.63
〃	90	2, 12	4, 25	19.65	0.35	0.31
〃	105	2, 17	5, 10	19.85	0.15	0.16
〃	120	2, 20	6, 05	19.95	0.05	0.08
〃	135	2, 23	6, 45	19.95	0.05	0.04
50	15	2, 35	0, 50	27.35	22.65	25.0
〃	30	2, 20	1, 35	38.10	11.9	12.5
〃	45	2, 35	2, 15	43.85	6.15	6.25
〃	60	2, 40	3, 05	46.95	3.05	3.13
〃	75	2, 35	3, 45	48.4	1.6	1.56
〃	90	2, 40	4, 10	48.75	1.15	0.78
〃	105	2, 15	5, 0	49.55	0.45	0.39
〃	120	2, 35	6, 0	49.75	0.25	0.2
〃	135	2, 30	7, 0	49.85	0.15	0.1
〃	150	2, 30	7, 0	49.90	0.1	0.05
〃	165	2, 35	8, 0	49.95	0.05	0.03

(II) Taking 400 cc. of the sample ($a=20$)

Total nitrogen (m)	Volume of distillate (S)	Time for boiling.	Time for distillation.	Quantities of nitrogen distilled.	Residual nitrogen (x)	
					obs. (± 0.05	cal.
mg.	cc.	′ ″	′ ″	mg.	mg.	mg.
5	20	3, 30	1, 0	2.45	2.55	2.5
〃	40	3, 05	2, 05	3.65	1.35	1.25
〃	60	3, 10	3, 15	4.30	0.7	0.63
〃	80	3, 0	4, 05	4.65	0.35	0.31
〃	100	2, 55	5, 10	4.80	0.2	0.16
〃	120	2, 50	6, 0	4.90	0.1	0.08
〃	140	2, 55	7, 05	4.95	0.05	0.04
20	20	2, 55	1, 02	10.9	9.1	10.0
〃	40	2, 53	1, 55	15.2	4.8	5.0
〃	60	2, 47	2, 57	17.6	2.4	2.5
〃	80	2, 45	4, 0	18.8	1.2	1.25
〃	100	2, 50	4, 50	19.4	0.6	0.63
〃	120	2, 50	6, 05	19.7	0.3	0.31
〃	140	2, 45	7, 0	19.8	0.2	0.16
〃	160	2, 55	8, 0	19.9	0.1	0.08
〃	180	3, 0	9, 0	19.95	0.05	0.04
50	20	3, 05	1 , 0	26.15	23.85	25.0
〃	40	3, 07	2, 0	38.15	11.85	12.5
〃	60	2, 50	3, 05	42.95	7.05	6.25
〃	80	2, 35	4, 0	46.8	3.2	3.13
〃	100	2, 53	5, 0	48.65	1.35	1.56
〃	120	2, 57	6, 03	49.3	0.7	0.78
〃	140	2, 55	7, 0	49.6	0.4	0.39
〃	160	3, 10	7, 50	49.8	0.2	0.2
〃	180	3, 0	9, 0	49.85	0.15	0.1
〃	200	3, 07	10, 0	49.95	0.05	0.05

Table II.

The rate of the nitrogen distillation by means of the ordinary method.

(I) Taking 300 cc. of the sample ($a=15$)

Total nitrogen (m)	Volume of distillate (S)	Time for boiling.	Time for distillation.	Quantities of nitrogen distilled.	Residual nitrogen (x)	
					obs. ($\pm$0.05)	cal.
mg. 20	cc. 15	′ ″ 4, 40	′ ″ 1, 25	mg. 11.3	mg. 8.7	mg. 10.0
〃	30	5, 0	2, 55	15.75	4.25	5.0
〃	45	5, 05	4, 30	17.9	2.1	2.5
〃	60	5, 0	5, 40	18.9	1.1	1.25
〃	75	5, 0	7, 0	19.45	0.55	0.63
〃	90	4, 45	8, 15	19.65	0.35	0.31
〃	105	4, 55	10, 30	19.8	0.2	0.16
〃	120	4, 35	12, 05	19.9	0.1	0.08
〃	135	4. 40	13, 35	19.95	0.05	0.04

(II) Taking 400 cc. of the sample ($a=20$)

Total nitrogen (m)	Volume of distillate (S)	Time for boiling.	Time for distillation.	Quantities of nitrogen distilled.	Residual nitrogen (x)	
					obs. ($\pm$0.05)	cal.
mg. 20	cc. 20	′ ″ 6, 0	′ ″ 2, 0	mg. 10.95	mg. 9.05	mg. 10.0
〃	40	5, 45	3, 50	15.65	4.35	5.0
〃	60	5, 55	5, 35	18.0	2.0	2.5
〃	80	5, 35	7, 30	19.0	1.0	1.25
〃	100	5, 55	9, 25	19.5	0.5	0.63
〃	120	5, 50	11, 35	19.7	0.3	0.31
〃	140	5, 55	13, 45	19.85	0.15	0.16
〃	160	6, 0	15, 45	19.95	0.05	0.08
〃	180	5, 50	17, 55	19.95	0.05	0.04

Studies of Netting Cords. V.
The Decrease of the Strength of Cords at the Knot.

By

Morisaburô Tauti, *Rigakuhakusi.*

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Cords which constitute a net snap in general at the knot. This may be considered to result from the decrease of the strength of cord at the knot. The cord is bent at knot. From the bending the decrease of the strength may result? The present paper will answer this question.

Any number of yarns or fibres are twisted one with others to make a thread, and two or three of the threads are twisted to a cord. The direction of the twist of thread and that of cord have the opposite sense to each other.

The center line of a thread may be assumed to construct a common helix around the center line of cord. So, when the center line of cord is bent in a circular arc of radius R, the center line of thread may be taken to construct a curve expressed by the following equation (1):

$$\left.\begin{aligned} x&=(R+r\cos\theta)\cos\varphi \\ y&=(R+r\cos\theta)\sin\varphi \\ z&=r\sin\theta \\ \theta&=\frac{2\pi}{\Phi}\varphi, \qquad R\Phi=h \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where r and h are the radius and the pitch of the helix of the center line of thread respectively. Then the length of a single turn of the center line of thread, S, is as follows:

$$\begin{aligned} S&=\int_0^{\Phi}\sqrt{(dx)^2+(dy)^2+(dz)^2} \\ &=\int_0^{\Phi}\sqrt{\left(\frac{2\pi r}{\Phi}\right)^2+(R+r\cos\theta)^2}\,d\varphi \\ &\fallingdotseq\sqrt{(2\pi r)^2+h^2}\left\{1+\frac{1}{4}\frac{h^2\left(\frac{r}{R}\right)^2(2\pi r)^2}{[(2\pi r)^2+h^2]^2}\right\} \end{aligned}$$

If no change takes place in the radius and pitch of the helix, the bending of cord must give rise to the elongation of the centre line of thread thus:

$$\Delta S=\frac{1}{4}\frac{h^2\left(\frac{r}{R}\right)^2(2\pi r)^2}{[(2\pi r)^2+h^2]^{\frac{3}{2}}} \quad \cdots\cdots\cdots\cdots\cdots\cdots(2)$$

This elongation might result only from the decrease of the radius of thread.

If any number of yarns, L mm in length, are put in parallel and twisted N times one with the others, and two or three threads thus prepared are again twisted n times in the opposite sense to make a cord, then, as the number of twists of the thread is $N-n$, the total length of the center line of thread is $\sqrt{L^2-(2\pi r)^2(N-n)^2}$, but it is equal to $\sqrt{(2\pi rn)^2+L'^2}$, L' representing the length of cord. Therefore.

$$L^2=(2\pi r)^2[n^2+(N-n)^2]+L'^2$$

Neglecting the elongation of yarn,

$$(2\pi r)^2[n^2+(N-n)^2]\frac{\Delta r}{r}+L'^2\frac{\Delta L'}{L'}=0$$

Putting $h=\frac{L'}{n}$ and $h'=\frac{L'}{N-n}$,

$$(2\pi r)^2\left[1+\frac{h^2}{h'^2}\right]\frac{\Delta r}{r}+h^2\frac{\Delta h}{h}=0 \quad \cdots\cdots\cdots\cdots\cdots(3)$$

The decrease of the radius of common helix constructed by the center line of thread and the elongation of the pitch of that helix follow the above equation (3). Then, the bending of cord is accompanied by the decrease of the radius of thread, given by the following simultaneous equations:

$$\frac{(2\pi r)^2\frac{\Delta r}{r}+h^2\frac{\Delta h}{h}}{\sqrt{(2\pi r)^2+h^2}}=\frac{1}{4}\frac{(2\pi r)^2\left(\frac{r}{R}\right)^2h^2}{[(2\pi r)^2+h^2]^{\frac{3}{2}}}$$

and $$(2\pi r)^2\left[1+\frac{h^2}{h'^2}\right]\frac{\Delta r}{r}+h^2\frac{\Delta h}{h}=0$$

Solving these equations,

$$-\frac{\Delta r}{r}=\frac{1}{4}\left(\frac{r}{R}\right)^2\frac{h'^2}{(2\pi r)^2+h^2} \quad \cdots\cdots\cdots\cdots\cdots\cdots(4)$$

The equation (4) represents the decrease of the radius of thread from which results the elongation of thread due to the bending of cord.

Assuming that a yarn constructs the common helix around the center line of thread and that the radius of that helix is equal to the

radius of the thread, r, the pitch of that helix, $\underset{\sim}{h}$, and the length of a single turn, S_0, are given as follows:

$$\underset{\sim}{h}^2=\left(\frac{L}{N-n}\right)^2-(2\pi r)^2$$

$$=(2\pi r)^2\left(\frac{n}{N-n}\right)^2+\left(\frac{L'}{N-n}\right)^2$$

$$=(2\pi r)^2\frac{h'^2}{l^2}+h'^2$$

$$=h'^2\left[1+\left(\frac{2\pi r}{h}\right)^2\right]$$

and

$$S_0^2=\left(\frac{L}{N-n}\right)^2$$

$$=(2\pi r)^2\left[1+\left(\frac{n}{N-n}\right)^2\right]+\left(\frac{L'}{N-n}\right)^2$$

$$=(2\pi r)^2\left[1+\frac{h'^2}{h^2}\right]+h'^2$$

$$=(2\pi r)^2+h'^2\left[1+\left(\frac{2\pi r}{h}\right)^2\right].$$

On common netting cords, as $\frac{2\pi r}{h}\fallingdotseq\frac{1}{3}$

$$\underset{\sim}{h}\fallingdotseq h' \quad \text{and} \quad S_0\fallingdotseq\sqrt{(2\pi r)^2+h'^2} \quad \ldots\ldots\ldots\ldots\ldots(5)$$

Equations (5) show that each yarn may be assumed to construct a common helix whose radius and pitch are r and h' respectively and whose axis is, on an average, the centre line of cord. Accordingly, the elongation of yarn resulted from the bending of cord is get from (2), putting h' in place of h, thus:

$$\Delta S_0=\frac{1}{4}\frac{(2\pi r)^2\left(\frac{r}{R}\right)^2h'^2}{[(2\pi r)^2+h'^2]^{\frac{3}{2}}}$$

Then the decrease of the radius of thread due to the bending of its centre line is given, on an average, by the following equation (6):

$$-\frac{\Delta r}{r}=\frac{1}{4}\left(\frac{r}{R}\right)^2\frac{h'^2}{(2\pi r)^2+h'^2} \quad \ldots\ldots\ldots\ldots 6)$$

because

$$\frac{(2\pi r)^2}{\sqrt{(2\pi r)^2+h'^2}}\frac{\Delta r}{r}+\frac{1}{4}\frac{(2\pi r)^2\left(\frac{r}{R}\right)^2h'^2}{[(2\pi r)^2+h'^2]^{\frac{3}{2}}}=0$$

As the decrease of the radius of thread results from the elongation and the bending of the centre line of thread, that decrease is expressed by (7)

$$-\frac{\Delta r}{r}=\frac{1}{4}\left(\frac{r}{R}\right)^2 h'^2\left[\frac{1}{(2\pi r)^2+h^2}+\frac{1}{(2\pi r)^2+h'^2}\right] \quad \cdots\cdots(7)$$

When the centre line of cord is bent in circular arc of radius R, the principal curvature of a yarn, $\frac{1}{\rho}$, may be given by the following:

$$\frac{1}{\rho^2}=\left(\frac{d^2x}{ds^2}\right)^2+\left(\frac{d^2y}{ds^2}\right)^2+\left(\frac{d^2z}{ds^2}\right)^2$$

$$(ds)^2=(dx)^2+(dy)^2+(dz)^2$$

$$x=(R+r\cos\theta)\cos\varphi$$

$$y=(R+r\cos\theta)\sin\varphi$$

$$z=r\sin\theta$$

$$\theta=\frac{2\pi}{\Phi}\varphi, \qquad R\Phi=h'$$

$$\therefore \quad \frac{1}{\rho^2}=\frac{\left(\frac{2\pi}{\Phi}\right)^4 r^2+4\left(\frac{2\pi}{\Phi}\right)^2 r^2\sin^2\theta+(R+r\cos\theta)^2+2\left(\frac{2\pi}{\Phi}\right)^2(R+r\cos\theta)r\cos\theta}{\left[\left(\frac{2\pi}{\Phi}\right)^2 r^2+(R+r\cos\theta)^2\right]^2}$$

$$-\frac{\left(\frac{2\pi}{\Phi}\right)^2(R+r\cos\theta)^2 r^2\sin^2\theta}{\left[\left(\frac{2\pi}{\Phi}\right)^2 r^2+(R+r\cos\theta)^2\right]^3}$$

$\frac{1}{\rho}$ has a maximum value at $\theta=0$, and

$$\left.\frac{1}{\rho}\right]_0=\frac{\left(\frac{2\pi}{\Phi}\right)^2 r^2+R+r}{\left(\frac{2\pi}{\Phi}\right)^2 r^2+(R+r)^2}$$

$$=\frac{1}{r}\frac{(2\pi r)^2+h'^2\frac{r}{R}\left(1+\frac{r}{R}\right)}{(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)}$$

$$= \frac{1}{r}\left[1 - \frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2 + h'^2\left(1+\frac{r}{R}\right)^2}\right] \quad \cdots\cdots\cdots\cdots (8)$$

The decrease of the radius of thread, $-\frac{\Delta r}{r}$, follows from the increase of pressure, $-k\frac{\Delta r}{r}$, which the yarns forming the outside layer of thread act upon the entire thread. Then, each yarn forming the outside layer is strained by the tension, τ, such as

$$\frac{1}{\sqrt{\pi} r_y}\frac{\tau}{\rho} = -k\frac{\Delta r}{r}$$

or

$$\tau = -\sqrt{\pi} r_y \rho\, k\frac{\Delta r}{r} \quad \cdots\cdots\cdots\cdots\cdots (9)$$

where r_y is the radius of the yarn. *So*, the breaking strength of cord must decrease as much as the sum of the tension, when the centre line of cord is bent. Thus, if the breaking strength of cord kept in straight state and kept in circular arc are expressed by T_0 and T respectively,

$$T_0 - T = 3\frac{2\pi r}{\sqrt{\pi} r_y}\tau$$

Substituting (7), (8) and (9)

$$T_0 - T = 3\frac{2\pi r}{\sqrt{\pi} r_y}\sqrt{\pi} r_y \frac{r}{1 - \frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2 + h'^2\left(1+\frac{r}{R}\right)^2}} k\frac{1}{4}\left(\frac{r}{R}\right)^2 h'^2 \times\left[\frac{1}{(2\pi r)^2 + h^2} + \frac{1}{(2\pi r)^2 + h'^2}\right]$$

Or

$$T_0 - T = \frac{3}{2}\pi r^2 \frac{\left(\frac{r}{R}\right)^2}{1 - \frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2 + h'^2\left(1+\frac{r}{R}\right)^2}} kh'^2 \times\left[\frac{1}{(2\pi r)^2 + h^2} + \frac{1}{(2\pi r)^2 + h'^2}\right] \quad \cdots\cdots (10)$$

To verify the above stated mechanism of the decrease of breaking strength in bending of cord, the writer measured the breaking load, T k_g, of various cord, d mm in dia., wound in one coil around a metal rod, D mm in dia.. Results of measurement[1] are given in Table I.

In the present case, the radius of thread, r, and the radius of curvature of the centre line of cord, R, may be expressed approximately by the following:

$$R=\frac{D+d}{2}$$

$$r=\frac{d}{\sqrt{12}}\fallingdotseq .29\,d \qquad \text{for 3-ply cord}$$

$$r=\frac{d}{\sqrt{8}}\fallingdotseq .35\,d \qquad \text{for 2-ply cord}$$

Hence we may put

$$\left.\begin{aligned} &\frac{r}{R}\fallingdotseq\frac{.58d}{D+d} && \text{for 3-ply cord}\\ &\frac{r}{R}\fallingdotseq\frac{.70d}{D+d} && \text{for 2-ply cord}\end{aligned}\right\}\quad\cdots\cdots\cdots(11)$$

Fig. 1 shows the relation between T and the value of $\left(\frac{r}{R}\right)^2\left/\left[1-\frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2}\right]\right.$ calculated by (11) from the data given in Table I. In Fig. 1, we see that the decrease of the strength in bending of cord nearly holds the eqation (10). And the slope of the probable straight line drawn in this figure gives the value of $\frac{3}{2}\pi r^2h'^2\times\left[\frac{1}{(2\pi r)^2+h^2}+\frac{1}{(2\pi r)^2+h'^2}\right]k$ in (10). k can be calculated both with the value of the slope and that of $\frac{3}{2}\pi r^2h'^2\left[\frac{1}{(2\pi r)^2+h^2}+\frac{1}{(2\pi r)^2+h'^2}\right]$ calculated from the data in Table I. Table II gives the results of the calculation.

On the other hand, the value of k might be estimated from the measurement of the decrease of the radius and the elongation of cord loaded in straight state. In this case, as the radius of curvature of a

1) This measurement was chiefly done by Mr. H. Yasuda and partly by the students of our institute.

Table I.[1]

$$D\text{mm}\quad Tk_g\quad \frac{r}{R}\quad \left(\frac{r}{R}\right)^2 \Bigg/ \left\{1-\frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2}\right\}$$

Dmm	Tk_g	$\frac{r}{R}$	$\left(\frac{r}{R}\right)^2$	$\left\{1-\frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2}\right\}$
Cotton cord				
3-ply $\nu=4$ $d=.63$mm $h=3.4$mm $h'=1.4$mm				
∞	5.5	.0		.0
2.80	5.2	.11		.029
2.13	5.0	.13		.035
1.76	4.9	.15		.053
1.05	4.5	.22		.11
.49	3.4	.33		.24
.32	3.7	.38		.31
3-ply $\nu=6$ $d=.80$mm $h=4.8$mm $h'=2.1$mm				
∞	8.1	.0		.0
2.76	7.7	.13		.048
2.42	8.1	.14		.056
1.74	8.1	.18		.095
1.26	8.3	.22		.15
1.01	7.5	.26		.17
.50	6.6	.36		.31
3-ply $\nu=8$ $d=.90$mm $h=5.4$mm $h'=2.5$mm				
∞	10.6	.0		.0
2.79	10.1	.14		.056
2.50	9.9	.15		.064
1.79	9.8	.19		.10
1.17	9.7	.25		.17
1.06	8.7	.27		.19
.49	7.4	.38		.35
Ramie cord				
3-ply $\nu=3$ $d=1.52$mm $h=6.9$mm $h'=4.3$mm				
∞	22.5	.0		.0
1.99	20.2	.25		.17
1.73	20.4	.27		.20
1.35	19.9	.30		.24
1.05	17.7	.34		.30
.79	14.8	.38		.36
.49	14.1	.44		.46
3-ply $\nu=4$ $d=1.77$mm $h=8.3$mm $h'=5.0$mm				
∞	27.9	.0		.0
17.5	25.7	.05		.01
2.86	25.3	.22		.14
2.15	24.3	.26		.19
1.35	22.4	.33		.28
1.06	20.4	.36		.33
3-ply $\nu=5$ $d=2.05$mm $h=10.8$mm $h'=5.6$mm				
∞	34.7	.0		.0
2.83	33.3	.24		.15
2.31	29.6	.27		.20
2.16	31.6	.28		.21
2.00	30.3	.29		.22
1.67	30.2	.32		.26
1.35	29.1	.35		.30
1.05	25.2	.38		.35
Manila hemp cord				
3-ply $\nu=12$ $d=1.15$mm $h=5.4$mm $h'=4.0$mm				
∞	18.1	.0		.0
2.86	17.4	.17		.10
2.00	17.7	.21		.15
1.63	15.0	.24		.19
1.35	15.1	.27		.23
1.06	14.4	.30		.27
3-ply $\nu=20$ $d=1.44$mm $h=7.1$mm $h'=4.7$mm				
∞	28.0	.0		.0
2.86	26.1	.19		.12
2.15	22.3	.23		.16
1.63	22.7	.27		.22
1.35	20.1	.30		.26
1.06	21.3	.33		.30
2-ply $d=1.47$mm $h=7.8$mm $h'=7.7$mm				
∞	24.7	.0		.0
2.86	21.7	.24		.21
2.13	21.8	.29		.28
1.63	19.0	.33		.35
1.35	19.1	.37		.42
1.06	16.0	.41		.49
3-ply $d=1.69$mm $h=7.8$mm $h'=12.1$mm				
∞	36.3	.0		.0
1.72	24.8	.29		.35
1.35	23.2	.32		.39
1.06	21.3	.36		.46
Japanese hemp cord				
3-ply $d=1.69$mm $h=10.5$mm $h'=16.3$mm				
∞	51.9	.0		.0
2.79	45.9	.22		.19
2.13	41.1	.26		.25
1.71	39.6	.29		.29
1.35	37.3	.32		.34
1.07	31.4	.35		.37
3-ply $d=2.19$mm $h=8.9$mm $h'=11.8$mm				
∞	79.5	.0		.0
2.84	71.1	.25		.25
2.15	65.8	.29		.31
1.63	62.0	.33		.37
1.35	52.1	.36		.43
1.06	51.0	.39		.47
3-ply $d=2.00$mm $h=10.5$mm $h'=16.3$mm				
∞	59.0	.0		.0
2.84	44.6	.24		.27
2.15	40.2	.28		.33
1.63	34.2	.32		.39
1.35	30.7	.35		.45
1.06	30.0	.38		.52

1) ν is the number of yarns composing each thread.

Fig. 1

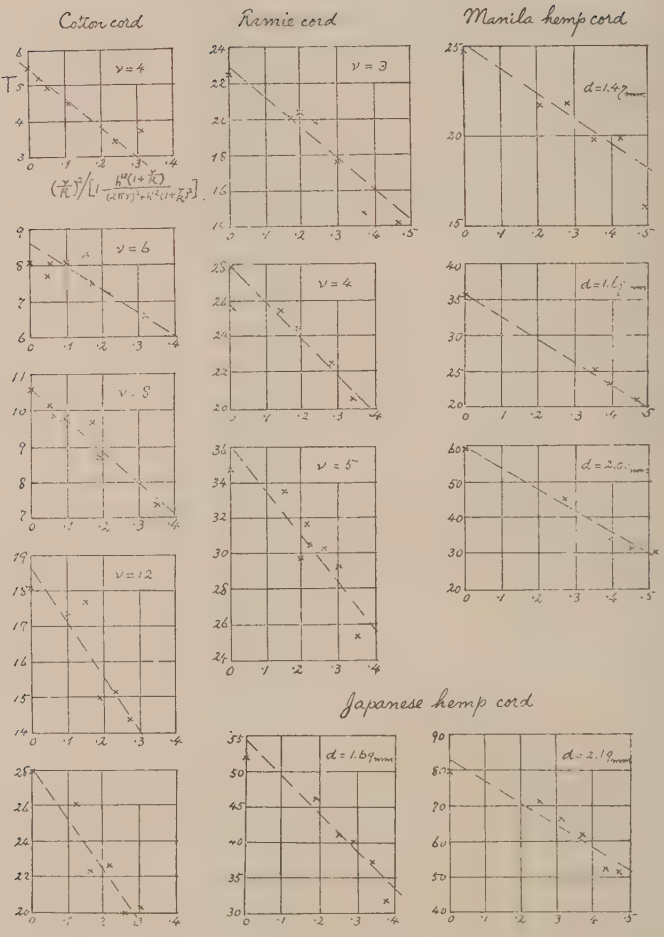

Cotton cord
Ramie cord
Manila hemp cord
Japanese hemp cord
ν = 4
ν = 3
d = 1.47 mm
ν = 6
ν = 4
ν = 8
ν = 5
ν = 12
d = 1.69 mm
d = 2.19 mm

Table II.

Cotton cord	$\frac{3}{2}\pi r^2 h'^2\left[\frac{1}{(2\pi r)^2+h^2}+\frac{1}{(2\pi r)^2+h'^2}\right]$	Slope of the most probable straight line in Fig. 1	Calculated value of k in $\frac{kg}{mm^2}$
3-ply $\nu=4$ $d=.63$mm	.12	8.3	69
„ 6 .80	.21	4.5	21
„ 8 .90	.29	8.7	30
„ 12 1.15	.66	15.	23
„ 20 1.44	.95	30.	32
Ramie cord			
3-ply $\nu=3$ $d=1.52$mm	.96	17.	18
„ 4 1.77	1.25	20.	16
„ 5 2.05	1.52	26.	17
Manila hemp cord			
2-ply $d=1.47$mm	2.1	14.	7
3-ply 1.69	3.4	33.	10
„ 2.00	5.2	60.	11
Japanese hemp cord			
3-ply $d=1.69$mm	2.7	52.	19
„ 2.19	4.5	62.	14

yarn is $\frac{1}{r}\frac{(2\pi r)^2}{(2\pi r)^2+h'^2}$ approximately, the increase of pressure which the yarns forming the outside layer of thread act upon the entire of thread is equal to $\frac{1}{\sqrt{\pi r_y}}\frac{1}{r}\frac{(2\pi r)^2}{(2\pi r)^2+h'^2}\frac{W}{3\nu}$, when the load of Wk_g is applied to the cord. Then

$$-k\frac{\Delta r}{r}=\frac{1}{3\nu\sqrt{\pi r_y}}\frac{(2\pi)^2}{(2\pi r)^2+h'^2}\Delta(rW)$$

or

$$k=-\frac{1}{3\nu\sqrt{\pi r_y}}\frac{(2\pi)^2}{(2\pi r)^2+h'^2}\frac{\Delta(rW)}{\frac{\Delta r}{r}} \quad \ldots\ldots\ldots (12)$$

where ν is the number of yarns composing each thread.

Neglecting the elongation of yarn,

$$(2\pi r)^2+h'^2=\text{const}$$

$$\therefore \quad (2\pi r)^2\frac{\Delta r}{r}+h'^2\frac{\Delta h'}{h'}=0$$

From (12)

$$k=\frac{1}{3\nu\sqrt{\pi r_y}}\frac{(2\pi)^2}{(2\pi r)^2+h'^2}\frac{(2\pi r)^2}{h'^2}\frac{\Delta(rW)}{\frac{\Delta h'}{h'}} \quad \ldots\ldots\ldots (13)$$

But, as $r_y=\frac{r}{\sqrt{\nu}}$, (12) and (13) become

$$k=-\frac{1}{3\sqrt{\nu}\sqrt{\pi}}\frac{(2\pi)^2}{(2\pi r)^2+h'^2}\frac{\Delta(rW)}{\Delta r} \quad \ldots\ldots\ldots\ldots (12')$$

Table III.

			Calculated value of k in $\frac{kg}{mm^2}$	
	Wkg	$r$mm[2)]	h'mm[3)]	by (13′)	by (12′)
Cotton cord 3-ply $\nu=4$					
	0	.259	1.25	31	8
	1.5	.221	1.32	30	19
	3.0	.207	1.38	56	49
	4.5	.201	1.41		
„ „	$\nu=6$				
	0	.326	1.76		
	2.0	.292	1.94	9	7
	5.0	.266	2.04	18	13
	8.0	.256	2.10	26	31
„ „	$\nu=8$				
	0	.374	2.16	7	5
	3.0	.323	2.38	11	10
	6.0	.300	2.48	14	17
	11.0	.280	2.59		
„ „	$\nu=12$				
	0	.451	3.45	4	4
	6.0	.386	3.77	6	10
	12.0	.364	3.90	6	19
	18.0	.354	4.03		
„ „	$\nu=20$				
	0	.593	3.96	2	3
	9.0	.495	4.49	5	10
	18.0	.472	4.67	5	14
	27.0	.457	4.84		
Ramie cord 3-ply $\nu=5$					
	0	.744	4.74	7	5
	12.0	.626	5.16	18	14
	24.0	.589	5.29	19	28
	36.0	.571	5.41		

$$k=\frac{1}{3\sqrt{\nu}\sqrt{\pi}}\frac{(2\pi)^2}{(2\pi r)^2+h'^2}(2\pi)^2\frac{r}{h'}\frac{\Delta(rW)}{\Delta h'} \quad \ldots\ldots\ldots(13')$$

The decrease of the diameter and the elongation were measured of several cords, being loaded by a tension meter of common type. Table III gives the results of measurement[1)] and the value of k calculated by the formulas (12′) and (13′).

Taking into consideration the ununiformness of test materials, many

1) This measurement was done by Mr. K. Miyosi.

2) r was calculated from the measured value of d by the formula: $r=.29\ d$.

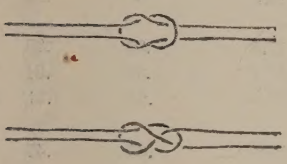
3) h' was calculated from the measured values of N, n and δ (rate of elongation) of moderately stretched cord, 50 cm in length, by the formula: $h'=\frac{5^{cc}(1+\delta)}{N-n}$.

difficulties met with in the measurement so far stated, the time effect[1] on the decrease of diameter and on the elongation of cord, the values of k calculated from the results of the two different experiments may be said to coincide with each other.

It is easily to be considered that the decrease of the strength of cord at the knot is mainly due to the bending of cord. Does any other agency, *e. g.*, the rubbing of cords against each other at the knot, have no remarkable influence upon the decrease of strength?

To answer the question, putting each pair of arms of a knot in parallel (Fig. 2), we measured the breaking load of that knot. In this case, if the strength of a cord forming the knot is T and the breaking load of the knot is W, then $T-\frac{W}{2}$ is the decrease of the strength of cord at the knot.

Fig. 2



Assuming that the decrease of strength is only due to the bending of cord, the value of $\left(\frac{r}{R}\right)^2 \Big/ \left[1-\frac{h'^2\left(1+\frac{r}{R}\right)}{(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2}\right]$ is found from Fig. 1 to give the decrease equal to the measured value of $T-\frac{W}{2}$, and corresponding value of $\frac{r}{R}$ is found from Table I and the value of $\frac{D}{d}$ is calculated by (11). Table IV gives the results of calculation.

1) On cotton cords whose thread is composed of 6 yarns, the students of our institute measured the diameter of cord after an hour loading. On the same materials, other students measured the elongation of cord after an hour loading (this Journal XXII. 4). From the results of these experiments, we calculate the value of k, thus:

			Calculated value of k in $\frac{k_g}{mm^2}$	
Wk_g	r mm	h' mm	by (13′)	by (12′)
0.5	.302	1.95	6	5
2.0	.272	2.09	9	5
3.5	.246	2.16	12	6
5.0	.226	2.20		

Comparing the calculated value of k with that given in Table III, we know that the time effect is remarkable.

Table IV.

				Flat knot				Herring knot			
				$\frac{W}{2}$	$\frac{r}{R}$	$\frac{D}{d}$	$\frac{W}{2}$	$\frac{r}{R}$	$\frac{D}{d}$		
				$1-\frac{\left(\frac{r}{R}\right)^2}{h'^2\left(1+\frac{r}{R}\right)}$				$1-\frac{\left(\frac{r}{R}\right)^2}{h'^2\left(1+\frac{r}{R}\right)}$			
				$(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2$				$(2\pi r)^2+h'^2\left(1+\frac{r}{R}\right)^2$			
Cotton cord											
3-ply	$\nu=4$	$d=.63$mm	4.7kg.	.09	.20	1.9	4.2kg	.15	.25	1.3	
„	6	.80	7.6	.15	.22	1.6	6.6	.31	.36	6	
„	8	.90	9.0	.18	.26	1.2	8.6	.23	.30	.9	
„	12	1.15	13.2	.36	.37	.6	12.8	.38	.38	.5	
„	20	1.44	20.1	.28	.31	.9	19.7	.30	.33	.8	
Ramie cord											
3-ply	$\nu=3$	$d=1.52$mm	18.5	.26	.31	.9	17.5	.32	.35	.7	
„	4	1.77	22.5	.27	.32	.8	21.7	.30	.34	.7	
„	5	2.05	31.8	.17	.25	1.3	29.9	.24	.31	.9	
Manila hemp cord											
2-ply		$d=1.47$mm	17.1	.57	.45	.6	16.2	.63	.49	.4	
3-ply		1.69	24.8	.35	.29	1.0	22.9	.39	.32	.8	
„		2.00	37.1	.36	.30	.9	34.0	.42	.34	.7	
Japanese hemp cord											
3-ply		$d=1.69$mm	35.3	.36	.34	.7	37.2	.30	.30	.9	
„		2.19	55.6	.44	.37	.6	52.1	.49	.40	.5	
						1.00				.75	

As seen in Table IV, $\frac{D}{d}$ depends on the kind of knot, but it does not depend on the sort of cord. Thus, we may say that the decrease of the strength at the knot is mainly due to the bending of cord and that the above stated mechanism of the decrease of strength holds good.

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